MAX PLANCK INSTITUTE FOR DYNAMICS OF COMPLEX TECHNICAL SYSTEMS MAGDEBURG

COMPUTATIONAL METHODS IN SYSTEMS AND CONTROL THEORY

WWU MÜNSTER

Towards a Benchmark Framework for Model Order Reduction in the Mathematical Research Data Initiative (MaRDI)

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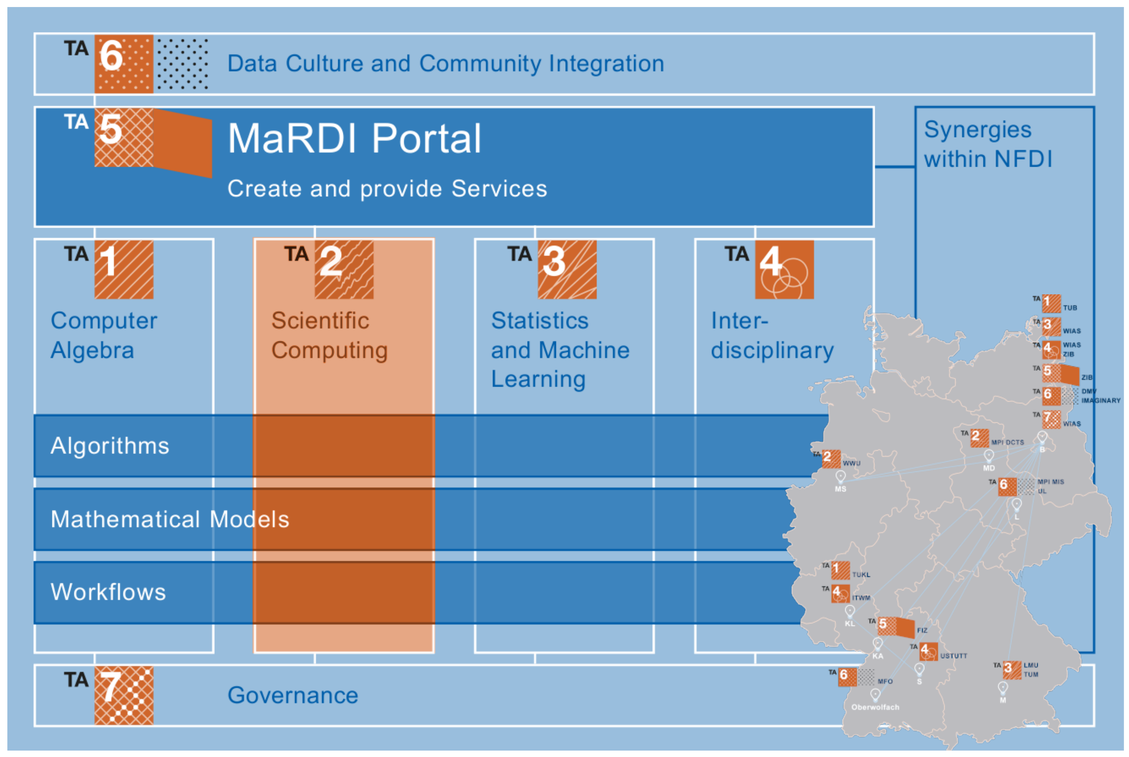
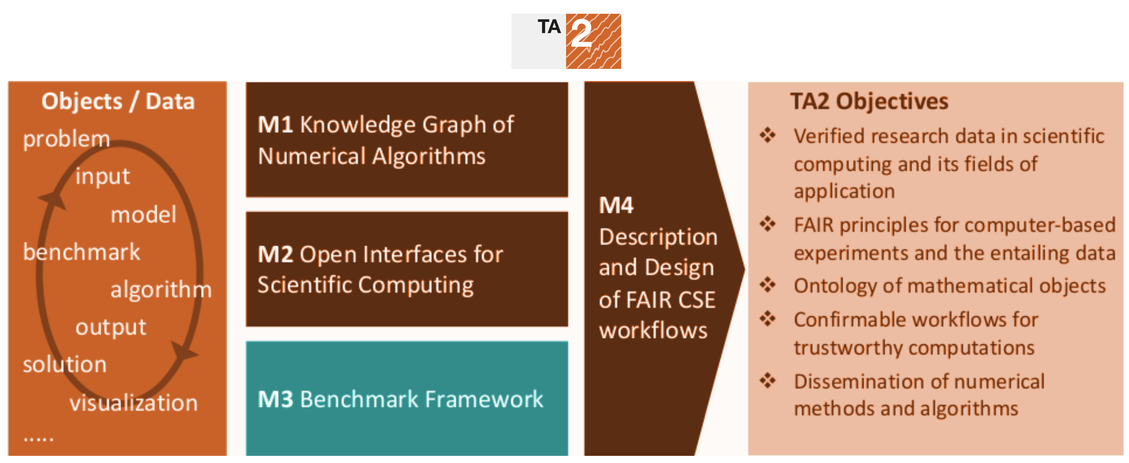
MaRDI: Mathematical Research Data Initiative



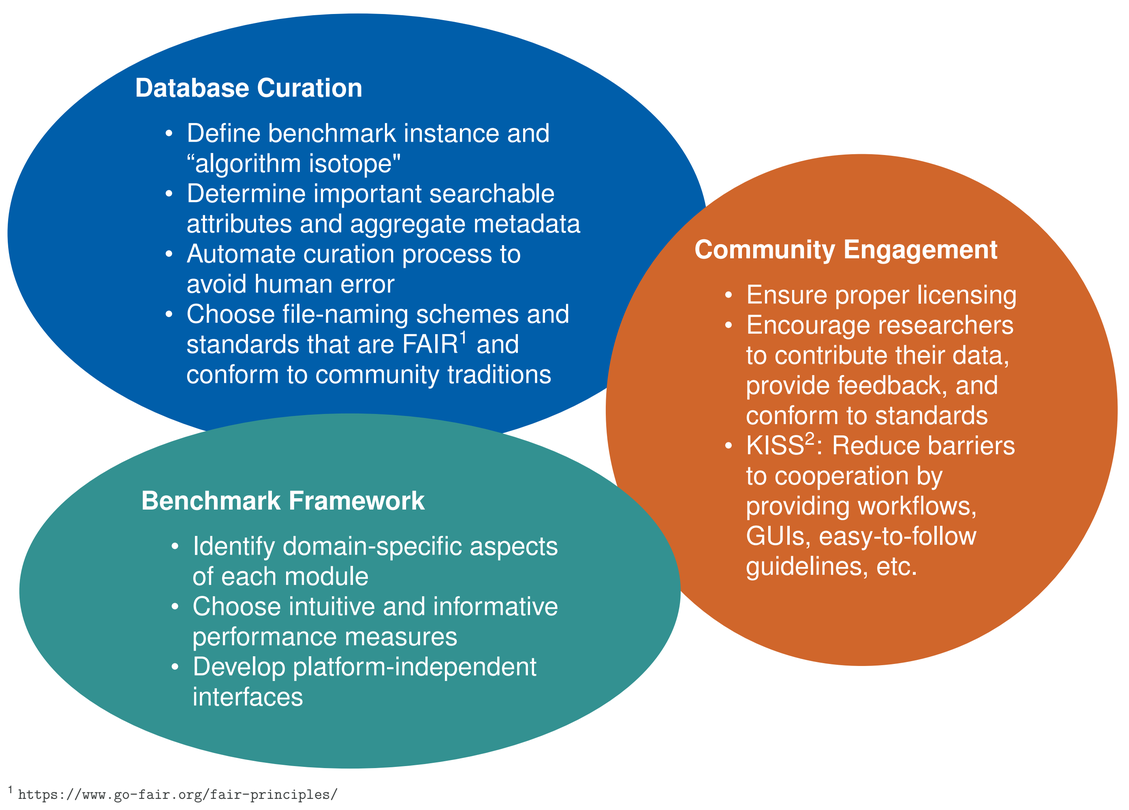


TA2-M3: MaRDIMark

A generic, extensible benchmark framework

Benchmarks	Algorithms	Driver	Analyzer	Explorer
data, metadata	pseudocode, software, metadata	interfaces, parameters, raw run data	post-processing, performance measures	visualization, human-readable reports

Domain-Independent Specifications and Challenges



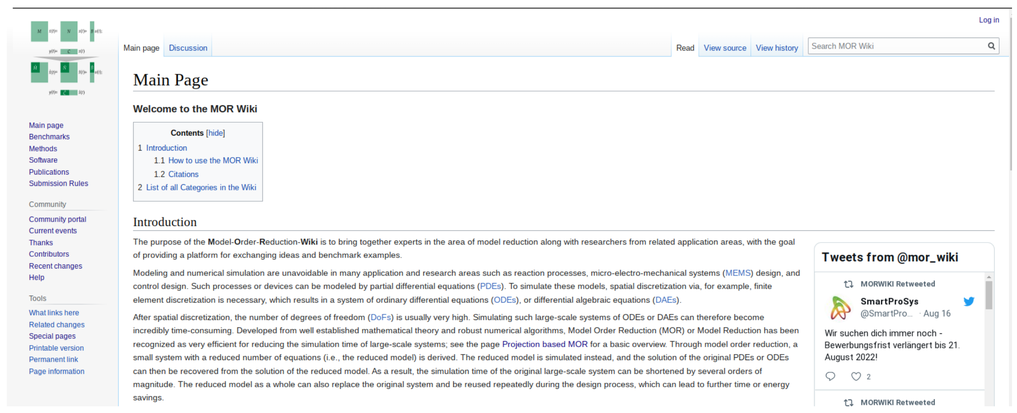
[1] https://www.go-fair.org/fair-principles/

[2]Keep It Simple, Silly https://en.wikipedia.org/wiki/KISS_principle

MORWiki: Model Order Reduction Wiki

Case study: MORWiki as a curated database

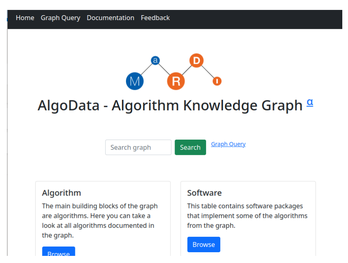
- Was launched in 2011 by MPI-CSC
- Comprises data and metadata for benchmarks, algorithms, and software
- Maintains guidelines for model classification and file formats



http://modelreduction.org/

Challenges

- Mathematical attributes like system stability, dissipativity, passivity, etc. need to be computed with fast, accurate, numerical linear algebra routines
- A single benchmark may have many instances / formulations
  - Procedural benchmarks have variable dimensions → fixed standard?
  - Second-order systems can be written as first-order systems → unique entries?
- Systems needing assembly require additional scripts, which must be standardized



https://algodata.mardi4nfdi.de/

Current tasks

- Ensure benchmark data is encoded uniformly
- Upload clean data to MOR Zenodo community: https://zenodo.org/communities/morwiki/
- Automate computation / validation of mathematical attributes

Next steps

- Improve database searchability via integration with AlgoData
- Add more benchmarks

MORB: Model Order Reduction Benchmarker

Case study: MORB as an instance of MaRDIMark

- Focuses on linear time-invariant (LTI) systems and MATLAB software for now
- Will serve as a template for other fields

Challenges

- Call external software without unnecessary overhead
- Determine what counts as a unique implementation of an algorithm (i.e., "algorithm isotope")
- Choose subroutines that compute measures (e.g., norms, MORscore [5], runtime) efficiently and accurately
- Establish standard for how to encode and handle nonlinear data

Current Tasks

- Write download tool and wrappers for algorithm isotopes
- Establish unit tests that encompass expected complications
- Transform outputs into human-readable, platform-independent reports

Next steps

- Generalize to other languages
- Expand tool to handle tougher problem types (e.g., nonlinear, parametric, etc.)
- Apply framework to other fields (e.g., $f(A)b$)

Selected References

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[2] Y. Chahlaoui and P. Van Dooren, *A collection of benchmark examples for model reduction of linear time invariant dynamical systems*, Tech. Report 2002–2, SLICOT Working Note, 2002. Available from http://www.slicot.org.

[3] J. Fehr, J. Heiland, C. Himpe, and J. Saak, *Best practices for replicability, reproducibility and reusability of computer-based experiments exemplified by model reduction software*, AIMS Mathematics, 1 (2016), pp. 261–281, https://doi.org/10.3934/Math.2016.3.261.

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[5] C. Himpe, *Comparing (empirical-Gramian-based) model order reduction algorithms*, in Model Reduction of Complex Dynamical Systems, P. Benner, T. Breiten, H. Faßbender, M. Hinze, T. Stykel, and R. Zimmermann, eds., vol. 171 of International Series of Numerical Mathematics, Birkhäuser, Cham, 2021, pp. 141–164, https://doi.org/10.1007/978-3-030-72983-7_7.

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